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Original

Maxillary sinus perforation by orthodontic anchor screws

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Abstract: To facilitate safe placement of orthodontic anchor screws (miniscrews), we investigated the frequency of maxillary sinus perforation after screw placement and the effect of sinus perforation on screw stability. Maxillary sinus perforations involving 82 miniscrews (diameter, 1.6 mm; length, 8 mm) were evaluated using cone-beam computed tomography. All miniscrews were placed in maxillary alveolar bone between the second premolar and first molar for anchorage for anterior retraction in patients undergoing first premolar extraction. The placement torque and screw mobility of each implant were determined using a torque tester and a Periotest device, and variability in these values in relation to sinus perforation was evaluated. Eight of the 82 miniscrews perforated the maxillary sinus. There was no case of sinusitis in patients with miniscrew perforation and no significant difference in screw mobility or placement torque between perforating and non-perforating miniscrews. The sinus floor was significantly thinner in perforated cases than in non-perforated cases. A sinus floor thickness of 6.0 mm or more is recommended in order to avoid miniscrew perforation of the maxillary sinus. (J Oral Sci 57, 95-100, 2015)

Keywords: temporary anchorage devices; TAD; mini implant.

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Introduction

Orthodontic anchor screws (miniscrews) are used to strengthen anchorages and ensure predictable tooth movement without reciprocal movement (1-7). Risk factors for miniscrew failure have been investigated in an attempt to improve success rates (8). Loosening of the miniscrew is thought to be related to inflammation around the placement site (9), overloading (8), cortical bone thickness and mineral density (10), screw design (9), and root proximity to the adjacent tooth (11). However, clinical miniscrew failure is frequent and is often caused by unknown factors. Risks associated with screw placement need to be clearly understood by orthodontists and patients. Complications during screw placement and after orthodontic loading can affect stability and patient safety.

The maxillary posterior alveolar region is frequently used as an insertion site, although incidental maxillary sinus perforation may occur in conjunction with descent of the maxillary sinus floor. Ardekian et al. (12) and Brånemark et al. (13) reported that immediately loaded dental implants that perforated nasal or maxillary sinuses exhibited no difference in implant stability. However, few studies have investigated the impact of miniscrew perforation of the maxillary sinus, including the rigid fixation of bone fragments in oral surgery. The effects of sinus perforation on the stability of low-caliber miniscrews have not yet been determined in humans. Sinus perforation may affect miniscrew stability and cause complications such as maxillary sinusitis.

Kravitz and Kusnoto (14) stated that if the maxillary sinus has been perforated, the miniscrew may not require immediate removal, due to its small diameter. They

Fig. 1 An orthodontic anchor screw (miniscrew) (diameter, 1.6 mm; length, 8 mm; total length, 11 mm).

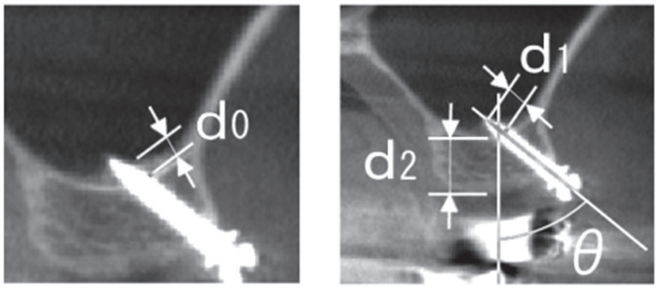

Fig. 2 Miniscrew perforation of the maxillary sinus, thickening of sinus mucosa at the placement site (d0), depth of screw penetration of the sinus (d1), distance from the alveolar crest to the bottom of the maxillary sinus (sinus floor thickness) (d2), and vertical inclination of the miniscrew (θ) were assessed using a tomographic cross-section corresponding to the miniscrew.

recommend that orthodontic therapy should continue and that the patient should be monitored for potential development of sinusitis and mucocele. To guarantee safe placement, researchers should verify in an *in vivo* clinical study that there is no development of sinusitis in cases of miniscrew perforation of the sinus. A case report using miniscrews (15) supported the findings of studies on maxillary sinus augmentation (sinus-lift procedure) (16-18). It found that while small, uncomplicated perforations may heal spontaneously, larger perforations in unfavorable areas can cause inflammation and other complications. Small miniscrew perforations without mobility or inflammation may heal spontaneously, but the possibility of complications such as sinusitis cannot be ignored in cases of perforation with mobility and inflammation.

Pazera et al. (19) determined the frequency of incidental maxillary sinus findings using cone-beam computed tomography (CBCT) images and identified incidental maxillary sinus findings in 65 of 134 (46.8%) orthodontic patients. Gracco et al. (20) used CBCT to determine the prevalence of incidental maxillary sinus findings in Italian orthodontic patients and found incidental maxillary sinus findings such as pseudocysts and mucosal thickening in half the patients. It is unclear whether maxillary sinus perforation induces sinusitis development and loosening of miniscrews in patients with incidental maxillary sinus findings, such as mucosal thickening.

We investigated the frequency of miniscrew perforation of the maxillary sinus and the effects of sinus perforation on screw stability. In addition, we discuss the relationships between sinus perforation, mucosal thickening when placing miniscrews, miniscrew stability, and the frequency of onset of maxillary sinusitis after screw placement.

Materials and Methods

The study included 45 patients (28 females, 17 males; average age 23.3 ± 8.9 years) who had miniscrews placed in the maxillary buccal alveolar bone between the second premolar and first molar at Nihon University Dental Hospital. In total, CBCT was used to evaluate 82 miniscrews. Cases in which miniscrews contacted adjacent tooth roots were excluded, to avoid the effects of root contact on miniscrew stability or loosening. This study was approved by the Ethics Committee of Nihon University School of Dentistry (2012-2). All patients consented to participate in this study.

Commercial self-drill miniscrews (ISA orthodontic anchor screw; diameter, 1.6 mm; length, 8 mm; Biodent, Tokyo, Japan) were used (Fig. 1). After administering local anesthesia, we placed the miniscrew in the buccal alveolar bone between the second premolar and the first molar of the maxilla. A hand screwdriver was used to place the miniscrew without a pilot hole so that it was inclined at 40° to 60° from vertical to the adjacent tooth axis, to avoid root contact. To prevent infection, an antibiotic (100 mg Flomox tablets, Shionogi, Osaka, Japan) was prescribed to each patient for 3 days after placement. The miniscrews were placed by three skilled clinicians (M.M., Y.U., N.S.) who each had more than 10 years of clinical experience. Using a torque tester (DIS-RL05; nominal accuracy ± 0.5%; Sugisaki Meter Co., Ltd., Tokyo, Japan), we measured maximum placement torque during terminal rotation of the miniscrew. To evaluate stability, a Periotest device (PTV) was used to assess miniscrew mobility (21). For each miniscrew, PTV values were obtained by holding the tip of the instrument's handpiece as parallel as possible to the bone

Table 1 Number of failures, according to maxillary sinus perforation status

Perforation		Failure	No perforation		Failure	*P* value
R	4	1	R	37	2	0.271
L	4	0	L	37	2	1
Total	8	1	Total	74	4	0.409

Table 2 Number of screws that perforated the maxillary sinus, according to depth of mucosal thickening

Mucosal thickening (mm)	No. of screws	Failures
0-1	1	0
1-2	6	0
3-	1	1

Table 3 Miniscrew stability, sinus floor thickness (SFT), and vertical inclination, according to maxillary sinus perforation status

		PTV	Placement torque (N·cm)	SFT (mm)	Vertical inclination (°)	Depth (mm)
Perforation	Mean	3.79	7.38	5.62	50.54	0.79 (0.25-1.50)
	SD	4.24	1.79	2.19	7.95	0.39
No perforation	Mean	4.04	7.53	10.54	53.78	-
	SD	4.47	3.00	3.59	12.9	
P value		0.981	0.913	0.000	0.472	

PTV: Periotest value, Depth: Depth of screw penetration of the sinus

surface, in accordance with the manufacturer's instructions. Each measurement was repeated three times, and the mean of the three values was calculated. To identify any incidental complications, such as root contact and/or root injury, an orthodontic force of ~2 N was applied to the miniscrew, and each participant underwent CBCT for post-placement examination. The CBCT diagnostic images were used to determine maxillary sinus perforation, vertical inclination of the miniscrew, and thickening of the sinus mucosa.

CBCT (3D Accuitomo, J. Morita, Kyoto, Japan; voxel size, 0.125 mm^3; X-ray tube voltage, 80 kV; current, 5.5 mA) was used for diagnostic imaging of the area around the site, immediately after placement. Using three-dimensional viewing software (One Volume Viewer, ver. 1.6.1.13; J. Morita), an examiner (R.S.) evaluated miniscrew perforation of the maxillary sinus, thickening of the sinus mucosa at the placement site, distance between the alveolar crest and bottom of the maxillary sinus (thickness of the sinus floor), vertical inclination of the miniscrews, and depth of miniscrew penetration of the sinus. For measurement of vertical inclination and penetration depth, a tomographic cross-section was fixed perpendicular to the occlusal plane corresponding to the miniscrew. On the cross-section, the angle between the long axis of the miniscrew and the tooth axis of the first molar was defined as the vertical inclination (Fig. 2). Each CBCT measurement was repeated three times, and the mean of the three values was calculated. Miniscrews that exhibited no mobility while an orthodontic force was applied during orthodontic treatment were considered successful, and miniscrews that were lost naturally or dislodged by mobility were considered failures. Incidental maxillary sinus findings caused by sinus perforation were evaluated using a panoramic tomogram, and lateral and frontal cephalograms were used for post-treatment diagnosis instead of CBCT, to reduce X-ray dose.

To evaluate intra-examiner error, we re-evaluated sinus perforation and screw inclination on randomly selected CBCT images from 10 subjects 2 weeks after the initial evaluation. Measurement error was assessed using Pearson's correlation coefficient. The chi-square test or Fisher's exact probability test was used to compare failure rate in relation to sinus perforation. The Mann-Whitney *U*-test was used to examine differences in sinus floor thickness, placement torque, vertical inclination of miniscrews, and PTV between perforated and non-perforated cases. The Breslow-Day test was used to estimate the common odds ratio. The Mantel-Haenszel test was then used to calculate the odds ratio (risk ratio) for risk of sinus perforation in relation to sinus floor thickness. These analyses were carried out using SPSS software (ver. 16.0; SPSS Japan, Tokyo, Japan). A P value <0.05 was considered to indicate statistical significance.

Results

Ten participants were randomly selected to undergo re-measurement 2 weeks after initial measurements. This reliability test showed a significant correlation (r = 0.83-0.90; $P < 0.01$) and confirmed the accuracy of the measurements. Of the 82 miniscrews, eight perforated the maxillary sinus between the second premolar and first molar (Table 1). Of the eight, one failed. This miniscrew had been inserted into a sinus with mucosal thickening >3 mm at the time of placement. Four of the 74 unperforated miniscrews also failed (Tables 1, 2). There was no significant difference in PTV, placement torque, or vertical inclination between perforating and non-perforating miniscrews (Table 3). The sinus floor was significantly

Table 4 Maxillary sinus perforation status, according to sinus floor thickness (SFT)

	SFT >6.0 mm		SFT <6.0 mm	
	No perforation	Perforation	No perforation	Perforation
R	35	1	2	3
L	34	2	3	2

Table 5 Odds ratios for sinus perforation associated with a sinus floor thickness of <6 mm as compared with a thickness of ≥6 mm

Breslow-Day	
Chi square	0.744
Degrees of freedom	1
P	0.388
Mantel-Haenszel test	
Common odds ratio	21.63
Log odds ratio	3.07
Standard error	0.86
95% confidential interval	4.05-115.53
P	0.000

thinner for perforated cases than for unperforated cases (5.62 ± 2.19 mm vs 10.54 ± 3.59 mm, respectively; Table 3). The mean depth of miniscrew penetration of the sinus was 0.79 ± 0.39 mm (range, 0.25-1.50 mm). There was no evidence of sinusitis development in post-diagnostic radiographic images of the perforated cases.

The common odds ratio was estimated using the Breslow-Day test ($P = 0.388$) (Tables 4, 5). The odds ratio (risk ratio) for maxillary sinus perforation was 21.63 ($P < 0.001$) when sinus floor thickness was <6.0 mm, as compared with a thickness of ≥6.0 mm.

Discussion

Miniscrews (length, 6-8 mm) are often used in the posterior alveolar region (1,3,5-7). Longer miniscrews are thought to perforate the sinus more frequently. Thus, we investigated the risk of sinus perforation with 8-mm miniscrews.

Liou et al. (22) measured the thickness of the infrazygomatic crest above the maxillary first molar, to provide guidance for inserting miniscrews. They recommended an insertion point 14-16 mm above the maxillary occlusal plane, with the maxillary first molar at an angle of 55° to 70° to the maxillary occlusal plane to avoid root contact. They noted that emergence of a screw head at the alveolar mucosa, but not the attached gingiva, frequently causes soft-tissue embedment, irritation, or infection around miniscrews. Interradicular placement in the posterior buccal region with attached gingiva is used more frequently, and information on sinus perforation and screw stability would be useful in guiding miniscrew placement in interradicular spaces.

Among the miniscrews placed at the interradicular space between the second premolar and first molar, 9.8% (8/82) perforated the maxillary sinus in the present study. However, none of the affected patients developed sinusitis. Although the prescribed antibiotic might have been sufficient to prevent infection, as Gracco et al. (15) observed, small, uncomplicated perforations with miniscrews may also heal spontaneously. In contrast, one of eight (12.5%) perforated miniscrews failed, and this failed miniscrew was inserted in a sinus that had >3 mm of mucosal thickening at the time of miniscrew placement. Miniscrew perforation of a sinus with mucosal thickening may not pose a high risk of sinusitis development but may cause loosening of the miniscrew. This should be assessed in a future study with a larger sample. Among the unperforated miniscrews, 5.4% (4/74) failed. There was no significant difference in failure rate between perforating and non-perforating miniscrews.

To evaluate the effect of screw stability on sinus perforation we measured PTV and placement torque as indices of initial miniscrew stability. There was no significant difference between perforated and unperforated cases in these indices of screw stability. The maximum depth of screw penetration of the sinus was 1.5 mm when placing 8-mm miniscrews at the maxillary interradicular space. Maxillary sinus perforation at a depth of ≤1.5 mm seems unlikely to affect miniscrew stability.

Vertical inclination of the miniscrew was 50° to 54°, and this did not significantly differ between perforated and non-perforated cases. Although miniscrew inclination is thought to be useful in avoiding root contact, Laursen et al. (23) reported that perpendicular insertion at the mid-root level only rarely interfered with the sinus, whereas apically inclined insertion increased the risk of sinus perforation. To avoid sinus perforation the skilled clinicians who placed the miniscrews in the present study controlled the vertical insertion angle when placing miniscrews in patients with descent of the maxillary sinus floor. In fact, vertical inclination of miniscrews placed in subjects with a sinus floor thickness <10 mm was significantly gentler (56.7° ± 12.0°) than that in those with a sinus floor thickness >10 mm (50.2° ± 12.3°; $P < 0.05$). Despite a flattened insertion, some miniscrews may perforate the maxillary sinus when the sinus floor is thin. This could explain the differences between past (23) and present findings. Sinus floor thickness was significantly thinner in the perforated cases (<6 mm) than in the non-perforated cases. A sinus floor thickness of <6.0 mm was assumed to be a risk factor for maxillary sinus

perforation; the odds ratio was therefore estimated using this value as a cut-off. The Mantel-Haenszel test showed a high odds ratio, 21.63 ($P < 0.001$). Thus, a sinus floor thickness of ≥6.0 mm is recommended in order to avoid maxillary sinus perforation with 8-mm miniscrews. However, as Baumgaertel and Hans (24) and Kravitz and Kusnoto (14) also reported, if perforation occurs, interruption of orthodontic treatment and miniscrew removal are not warranted because neither sinusitis development nor a decline in screw stability was seen in the present perforated cases.

In a study of dry adult human skulls, Baumgaertel and Hans (24) concluded that maxillary sinus perforation is likely when inserting 6 mm or longer miniscrews into the infrazygomatic crest. As mentioned above, the maximum depth of screw penetration of the sinus was 1.5 mm for 8-mm miniscrews. Thus, a 6 mm or shorter miniscrew is recommended if maxillary sinus perforation must be avoided when inserting miniscrews at the interradicular space between the second premolar and first molar.

To ensure safe miniscrew placement, we investigated the frequency of maxillary sinus perforation after screw placement and the effects of sinus perforation on screw stability. Approximately 10% of miniscrews perforated the maxillary sinus, but maxillary sinus perforations ≤1.5 mm in depth are unlikely to affect screw stability. Small, uncomplicated perforations of the maxillary sinus by miniscrews may heal spontaneously. To avoid maxillary sinus perforation, the thickness of the sinus floor should be >6.0 mm or the screw length should be <6 mm.

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